Second Substitute Specification 09/827,462

METHOD FOR PRODUCING CUTTING TOOLS

CROSS-REFERENCE TO RELATED APPLICATION

This is a divisional of application number 09/253,212 filed February 19, 1999 and now U.S. Patent 6,241,431, which claimed priority from European Patent application number 99 103093.3 file February 17, 1999.

FIELD AND BACKGROUND OF THE INVENTION

Definitions

In the present specification hard material means a compound, namely a carbide, oxide, oxycarbide, but in particular a nitride, nitrocarbide, oxynitride or nitrooxycarbide, of at least two of the metallic elements listed in the following, in particular of Ti and Al. Metallic elements means Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W and Al.

If within the scope of the present application reference is made to a change of the composition of the hard material layer material in the active edge region, this means a difference of at least 2 at% of a hard material layer metal component between a hard material layer in the active edge region and a hard material

layer in the remaining regions of the tool.

Analogously, no change exists if the stated difference is less than 2 at%, in particular less than 1 at%.

Machining cross section f a_p means the product "Vorschub x Schnitttiefe" {Advance x cutting depth} according to DIN 6580, Section 11.1.1, "Bewegungen und Geometrie des Zerspanungsvorgang" [Motions and Geometry of the Machining Process] (DN 6580, Oct. 1985).

German Patent DE 38 25 399 as well as European Patent EP 0 352 545 disclose coating tools by means of a vacuum process with a layer of hard material, and therein especially with a (Ti,Al)N hard material layer. The coating takes place such that in the active edge region, *i.e.* in the region of the cutting edges, the hard material layer material has a changed composition compared with that on the remaining tool regions: according to DE 38 25 399 as well as EP 0 352 545 at the active edge regions of drills a thinning out of the aluminum is realized which is distinguishable on the tools by the reddish or yellowish coloration of these regions. Thinning-out ratios of 5 at% or 2 percent by mass of the Al are declared.

SUMMARY OF THE INVENTION

The process discovered, namely to change the hard material layer composition in the active edge region, is fundamentally represented as a measure for attaining a significant improvement of the quality of the coating.

The invention starts from the understanding that generally, tools have a hard material layer in their active edge region which is substantially, and within the scope of measurability, an unchanged material composition. In contrast, the composition of the hard material layer in the active edge region is changed relative to the hard material layer composition on the remaining tool regions according to the present invention. The invention proposes a process for the protective coating of machining tools as well as a set of at least two tools, by means of which substantially improved specific working properties are attained. In particular, working properties such as the service life of the tool or decrease of the tool wear, are improved.

According to the process of the invention, a hard material layer is applied onto the basic tool body but is selected for the specific stress the tool is meant to endure. The composition of the hard material layer in the active edge region is either left with minimum changes relative to the composition of the hard material layer in the remaining coating regions on the tool basic body or is intentionally changed. The former, *i.e.* constant composition, is realized if the primary requirements to be made of the tools relate to adhesive strength of the hard material layer and only secondarily to hardness of the hard material layer. The second, in contrast, is realized if the primary requirements to be made of the tools relate to hardness of the hard material layer and only secondarily to adhesive strength of the hard material layer.

According to the invention it was found that by changing or not changing the compositions of the hard material layers in the

active edge regions as a function of the working purpose of the tools, that is, by either providing a hard material coating of constant composition or a hard material coating of varying composition in the active edge region, critical improvements were realized. If tools for given applications, are coated with the wrong coating technique of the two mentioned, often an impairment of the tools' working properties, in particular tool life, results.

It could be shown, for example, that according to EP 0 352 545 with a thinning-out of the coating only in a few fields of machining, better or at least equally good results can be achieved, compared to the application of corresponding tools with a lower or no, at least not measurable, difference in the concentration of the hard material layer. It should be pointed out, in particular, that the example mentioned in EP 0 352 545 with respect to service life of twist drills, based on the representative comparisons made according to the present invention, is erroneous in the case where two completely identical, except for stated coating difference, and identically coated drills are present. The phrase completely identical here means an application of the same coating processes, in particular arc or sputtering processes, on identical tool bodies, and the adjustment of the realized or not realized concentration difference exclusively by adjusting the voltage applied on the basic tool body during the coating with respect to ground or reference potential, referred to as bias voltage U_{bias} in the following, and/or of the reactive gas partial pressure $p_{reactiv}$ in the vacuum coating receptacle with further process parameters remaining unchanged.

It can be seen that the prior known thinning-out in the active edge region can effect critical disadvantages in the use of the tool, and that consequently it is necessary to assess very carefully according to the invention, which process is applied at which time, for example, by the fact that precisely the aluminum depletion of the hard material layer in the active edge region has negative effects on wear through thermal stress of the hard material layer since through the aluminum thinning-out potentially, now less aluminum reaches the surface of the hard material layer through diffusion and no continuous thermally insulating aluminum oxide layer can be formed there. The Al_2O_3 layer on the surface is simultaneously worn out during the working process and formed again through Al diffusion. But precisely this phenomenon can critically influence the durability of the hard material layer with aluminum component under specific conditions.

According to the invention as explained in the following examples, it could be shown that tools with a hard material layer, in particular a (Ti,Al)N layer, comprising only a low or no longer measurable composition change of the material of the hard material layer in the active edge region, in many applications yield a substantially better service life, even with increased cutting efficiency, than other tools that are otherwise identical, with a composition change of the hard material layer in the active edge region. Especially good results can be achieved, in the case given first, if, in the active edge region, the change of one of the metal components of the hard material layer is less than 2 at%, preferably it is maximally 1 at% or no longer measurable.

Following another feature of the invention, when using arc vaporization for depositing the hard material layer, an as much as possible unchanged hard material layer composition in the active edge region is attained when the ratio U_{BIAS} - of the electric basic tool body voltage relative to reference potential, usually ground potential - to the partial pressure of the reactive gas $p_{reactiv}$, has the following range of values:

$$1 \times 10^{-3} \leq U_{BIAS}/p_{reactiv} \leq 4 \times 10^{3},$$

with the unit of voltage being "volt" and the unit of pressure "mbar".

Furthermore the invention produces drills, roughing milling cutters, peripheral milling cutters and hobbing machines with as much as possible unchanged composition of the hard material layer in the active edge region, and front-end milling cutters and ball-end milling cutters with changed composition of the hard material layer in the active edge region.

It was in particular found that the composition of the hard material layer in the active edge region of the tools should be unchanged, as far as possible, if these tools are intended for the working of relatively large voltage or cross sections and for low cutting rates; however, tools should be prepared with a changed composition of the hard material layer in the active edge region if the tools are intended for relatively low voltage machining cross sections but relatively high cutting rates.

A further criterion for making the selection according to the invention, of the type of hard material coating in the active edge region of the tools, is for the working of materials with a

hardness of at most 45 Rockwell (HRS) and a tensile strength up to at most 1500 N/mm^2, preferred for the working of heat-treatable steels, high-alloy and stainless steels as well as of nonferrous metals, to carry out the coating with hard material in the active edge region as much as possible without changing the composition. The same applies to tools whose active edges in use are simultaneously subjected to different cutting rates, such as in particular, drills on which a minimum cutting rate occurs at the tip of the drill and a high rate on the drill periphery.

Basic tool bodies are coated in the active edge region with changed composition of the hard material layer, which are intended for the machining working of materials with a hardness of more than 45 Rockwell (HRC) and with a tensile strength of more than 1500 N/mm^2, in particular for operations involving the removal of hard metal by cutting tools, for example, instead of grinding or erosion processes.

In the following AISI refers to known materials categorized by the American Iron and Steel Institute and DIN refers to materials categorized by the Deutsches Institut für Normung (German Standards Institute). Other ~~know~~ known standards are also used to identify other material types.

It has in particular been found, that

- indexable inserts for turning tools and for materials AISI 304SS or DIN 1.4306 to be worked,

- indexable inserts for peripheral milling cutters for

materials AISI 4140 or DIN 1.7225 to be worked,

- indexable inserts SEE 42TN for milling cutters for material SKD 61 (HRC 45) to be worked,

- hard metal roughing shank-type milling cutters for materials DIN 1.2344 to be worked in dry working, as well as

- HSS drills for materials AISI D3 or DIN 1.2080 as well as GG 25 to be worked with emulsion lubrication

should be realized as much as possible with unchanged composition of the hard material layer in the active edge region; however

- hard metal roughing shank-type milling cutters for materials DIN 1.2311 to be worked with emulsion lubrication

- hard metal front-end milling cutters for materials AISI D2 or DIN 1.237 to be worked

- hard metal ball-end milling cutters J97 for dry working of DIN 1.2343, 49.5 HRC, preferably with changed composition of the hard material layer in the active edge region.

Further, at least two tools are therein provided, one for a first specific application operation in which primarily high

adhesion strength of the hard material layer is required, however, only secondarily high hardness of the hard material layer, and a second tool, during the application of which primarily high hardness of the hard material layer is required and only secondarily high adhesion strength of this layer.

In this tool set according to the invention, the first tool is coated in the active edge region with substantially uniform composition of the hard material layer, however the second one with varying composition of the hard material layer.

Whether or not a tool is provided with a hard material coating whose composition in the active edge region is changed, is often evident by the coating coloration of the tool in the active edge region, thus typically for (Ti,Al)N layers with Al depletion in the active edge region through its yellowish or reddish coloration in stated region.

Through the present specification and the claims, the relevant expert gains clear instructions, based on which criteria he is to investigate, which active edge hard material coating techniques lead to better tool application behavior. Even when in specification and claims specific tool types as well as their type of application and the materials to be worked are specified, this is not to be understood to be conclusive for the expert but rather he recognizes, based on the evaluation of the useful coating type for further tools for further application fields and materials, considered by analogy, which coating technique is to be applied, or he obtains the advice first of all to try which of the two coating techniques leads to better results.